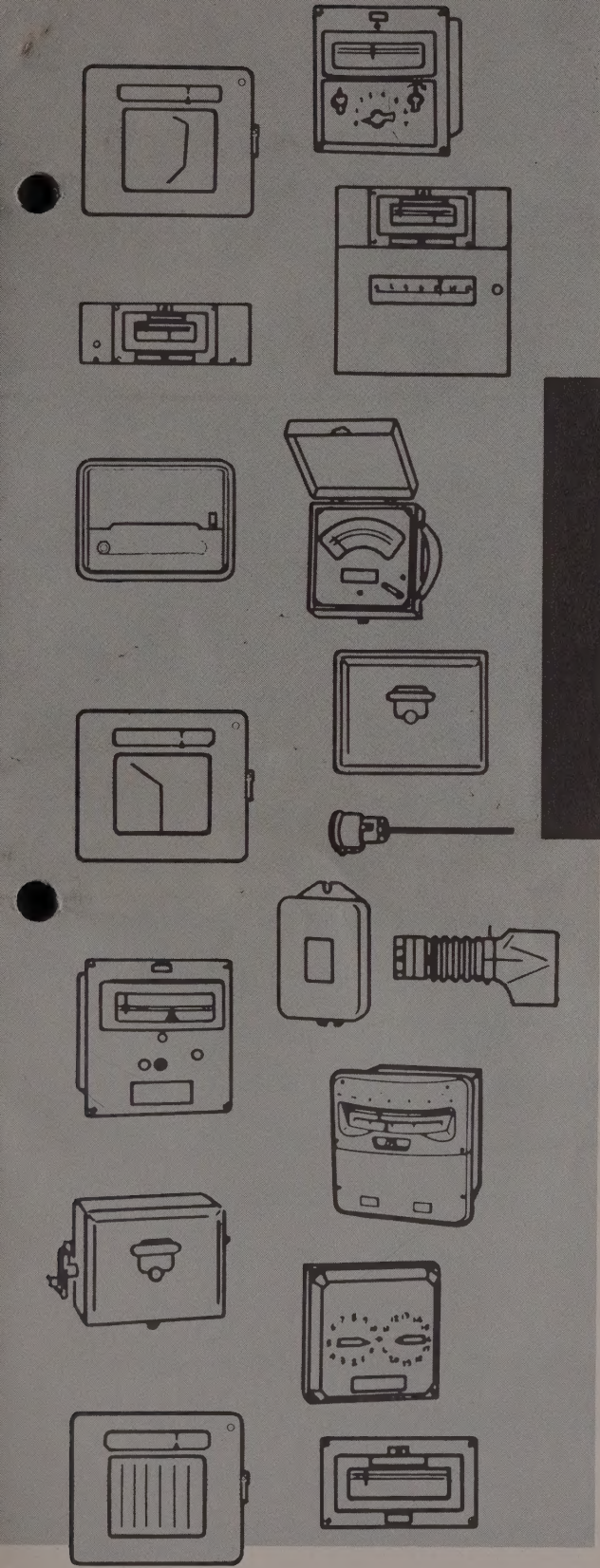
F-9563-1

(Effective with Serial No. 26GQ748)



INSTRUCTION MANUAL

Series 350 Reference Voltage Source

MP MASTER
MA32098

BARBER COLMAN

BARBER-COLMAN COMPANY

Industrial Instruments Division • Rockford, Ill., U. S. A.

SERIES 350 REFERENCE VOLTAGE SOURCE

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INSTRUCTION MANUAL

FOR

SERIES 350 REFERENCE VOLTAGE SOURCE

General Description

The Series 350 has been designed as a component for use with the null balancing galvanometer type indicating controller of the 400 Series. It is essentially a source of constant voltage adjustable to an amount equivalent to control point temperature for a particular thermocouple calibration, and used to oppose the thermocouple EMF to achieve null balance at control point. With a null balance indicator, temperature deviation from set point is indicated rather than actual temperature.

The combination of this device with a zero-center 400 Series instrument gives a measuring system particularly suited for critical control applications requiring extreme measuring sensitivity. It is recommended that the process for which it is used incorporate minimum time lags compatible to 5 per cent or less proportioning band.

This instruction information applies to any of the production models in the 350 series as follows:

Description	Model Numbers		
	Single Range	Double Range	Triple Range
Without cold junction temperature compensation and with digital readout dial calibrated in millivolts.	351M	352M	353M
With cold junction temperature compensation and with digital dial calibrated in millivolts or temperature.	351T	352T	353T

Mounting Instructions

The Series 350 reference voltage source is usually mounted separately from the Series 400 instrument housing when installed in a panel.

Flush mounting of the Series 350 case is accomplished by use of brackets furnished. Terminal access is from the rear. See outline and mounting dimensions below.

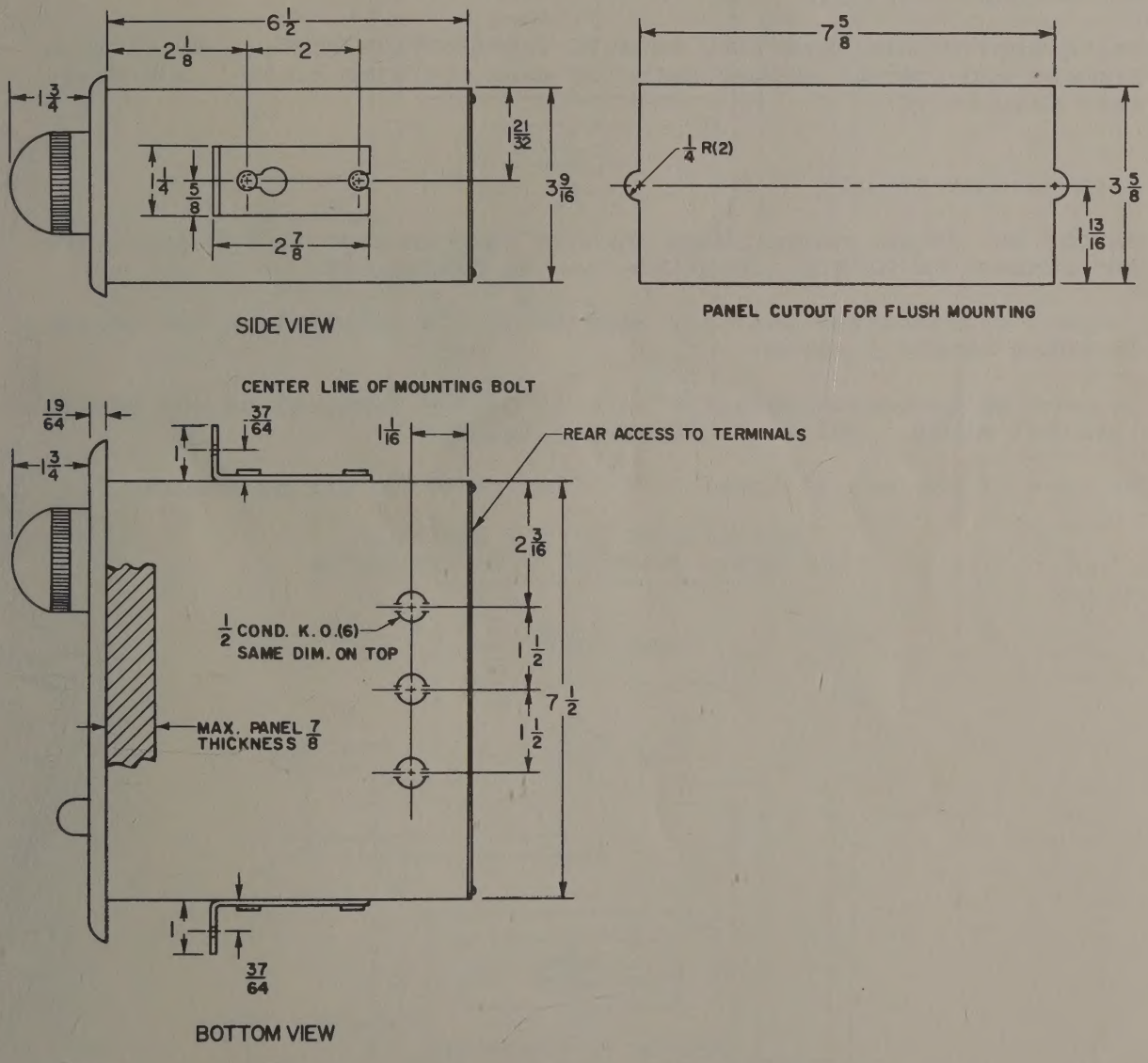


Fig. 1

Series 350 Layout and Mounting Dimensions

Wiring

Instrument Power:

Connect device to same 120v 60c source used for the Series 400 Controller. Wire to L1 and L2 Terminals on rear of Series 350 chassis. Remove four screws and remove rear plate. The chassis is removable from the front only. Thread 14 ga. wires through grommets and connect.

Thermocouple Wiring:

Using appropriate lead wire to suit thermocouple type, pass through grommet and connect proper polarity negative wire to TC - and positive wire to TC +.

Galvanometer Wiring:

Thread No. 14 ga. copper wire through same grommet as T/C lead wire and connect to GALVO+ and GALVO- on the Series 350.

Connect galvanometer positive wire to GALVO+ terminal on 400 Series lefthand terminal strip.

Connect galvanometer negative wire to GALVO- terminal on 400 Series terminal strip. See wiring diagram Fig. 2.

In case of the use of Model 407P-S279, refer to wiring diagram Fig. 3.

EXTERNAL WIRING DIAGRAM FOR MODEL 400 - SERIES S310 AND MODEL 350

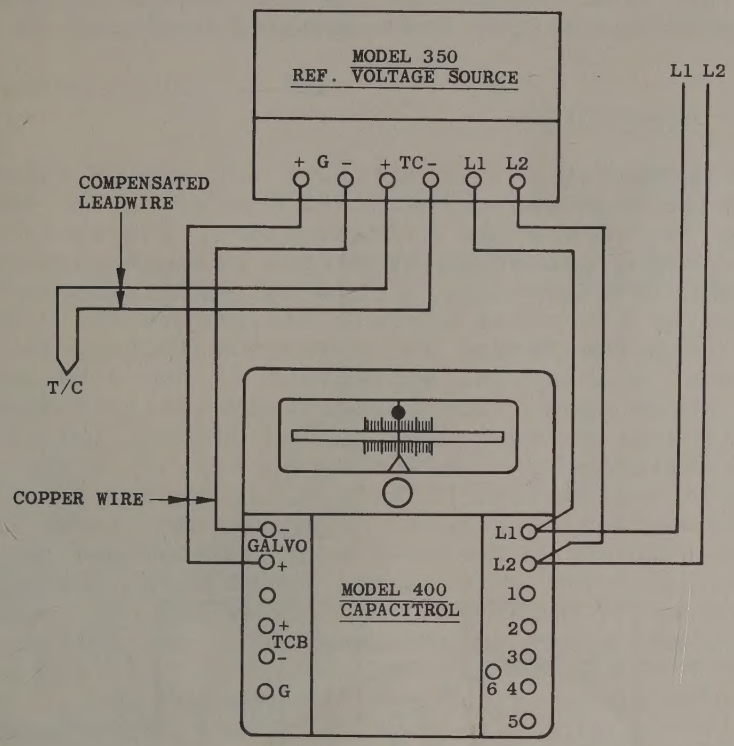


Fig. 2

EXTERNAL WIRING DIAGRAM FOR MODEL 407 S310 S279 AND MODEL 350

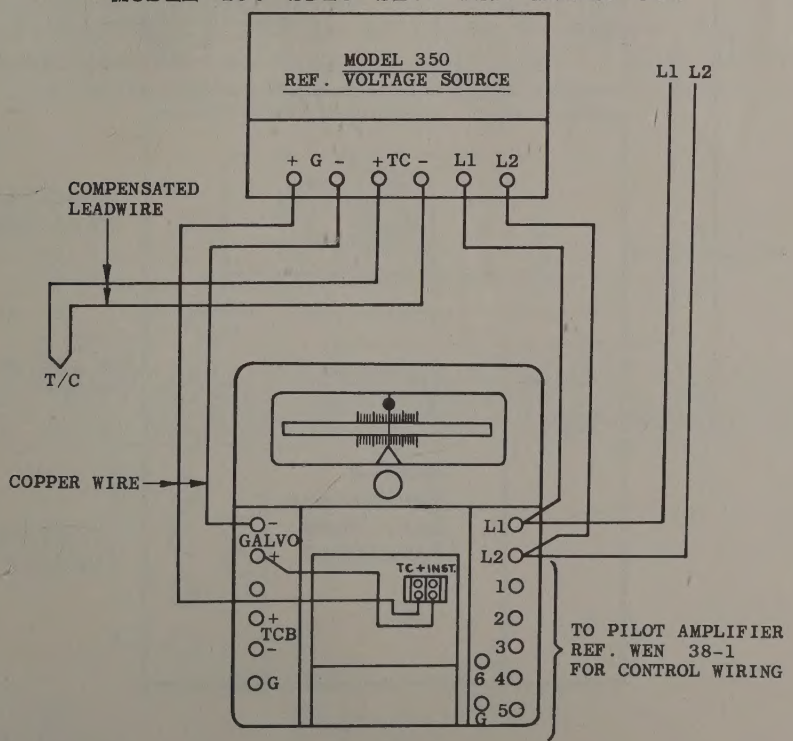


Fig. 3

Control Considerations

Refer to instruction book for the particular Series 400 controller instrument used with the Series 350 measuring system.

Measuring Circuit Description

Refer to block diagram Fig. 4. Basically, the system consists of three parts - the thermocouple or millivolt source, the Series 350 Reference Voltage Source and the galvanometer. The thermocouple or other source develops a potential by virtue of heat difference between the hot and cold junction. This potential results in a current as determined by the total circuit resistance and a bucking voltage produced from the Series 350 Reference Voltage Source. The Series 350 generates a potential equivalent to the dial setting and contains circuit resistance. The galvanometer deflects in an amount proportional to circuit current, recognizes current polarity and contains circuit resistance.

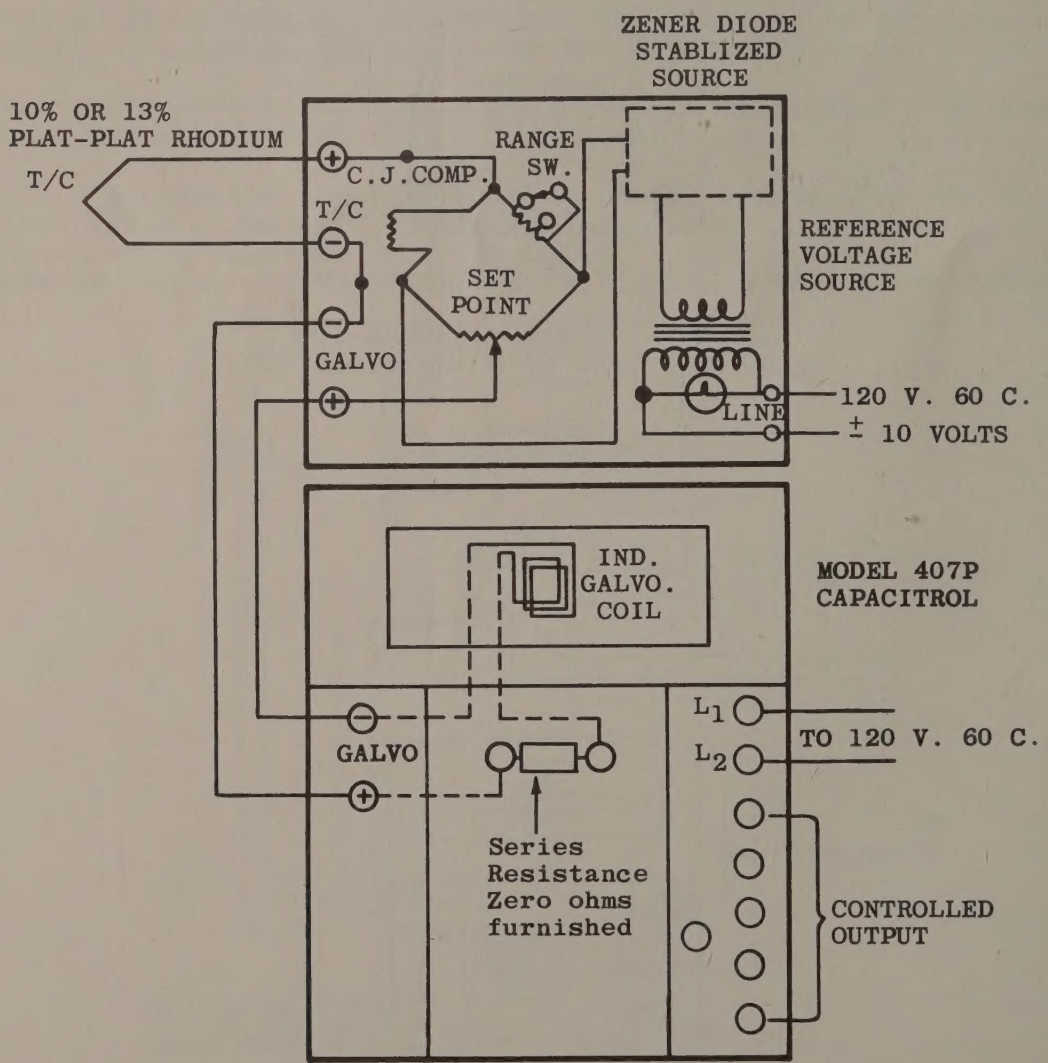


Fig. 4

The Model 350 reference voltage source is wired such that its polarity is bucking the thermocouple potential. The galvanometer is in series and recognizes the current which flows due to the unbalance between the T/C and Reference Voltage Source (RVS) potentials.

$$\text{Galvo current} = \frac{\text{EMF}_{T/C} - \text{EMF}_{RVS}}{R_{T/C} + R_{RVS} + R_{Galvo} + R_{\text{lead wires}}}$$

When the current is zero, the thermocouple output is equal to the Series 350 output and the galvanometer indicates a null balance condition.

Calibration of Dial for Thermocouples

The dial controls the output potential value of the Series 350. The output is linear. When calibrated in degrees temperature and per thermocouple materials, the dial reading is not absolutely exact because thermocouples do not have linear potential output versus temperature. However, when small temperature spans are utilized the error is diminished. The Series 350 is calibrated so as to give a calibration approximating the curve and cutting the curve at two or more points. See Fig. 5. In the example shown (0-800°F range using Plat./Plat. 13 Rho.), the midrange of the thermocouple EMF is + 1.794 mv. This is equivalent to 458°F. With a linear millivoltage output of the instrument, tracking line B as shown on the graph, this amount of millivoltage will read out as 429°F. Thus the instrument is in error by 29°F, on the low side, at the midpoint of the range. You will note that as the cross-over points are approached the error becomes less, eventually reaching zero, but at either extreme end of the range the error is again maximum although of opposite sign. The list of Series 350 standard ranges at the back of this manual also shows the maximum calculated limits of error for each range and calibration.

The above example illustrates that 800° cannot be reached with this calibration and range. Ranges should be specified to cover temperatures required.

Note: The 0-800 platinum 13% rhodium example is an extreme case and only intended to illustrate the T/C non-linearity and linear calibration method. Refer to range tables for actual recommended ranges.

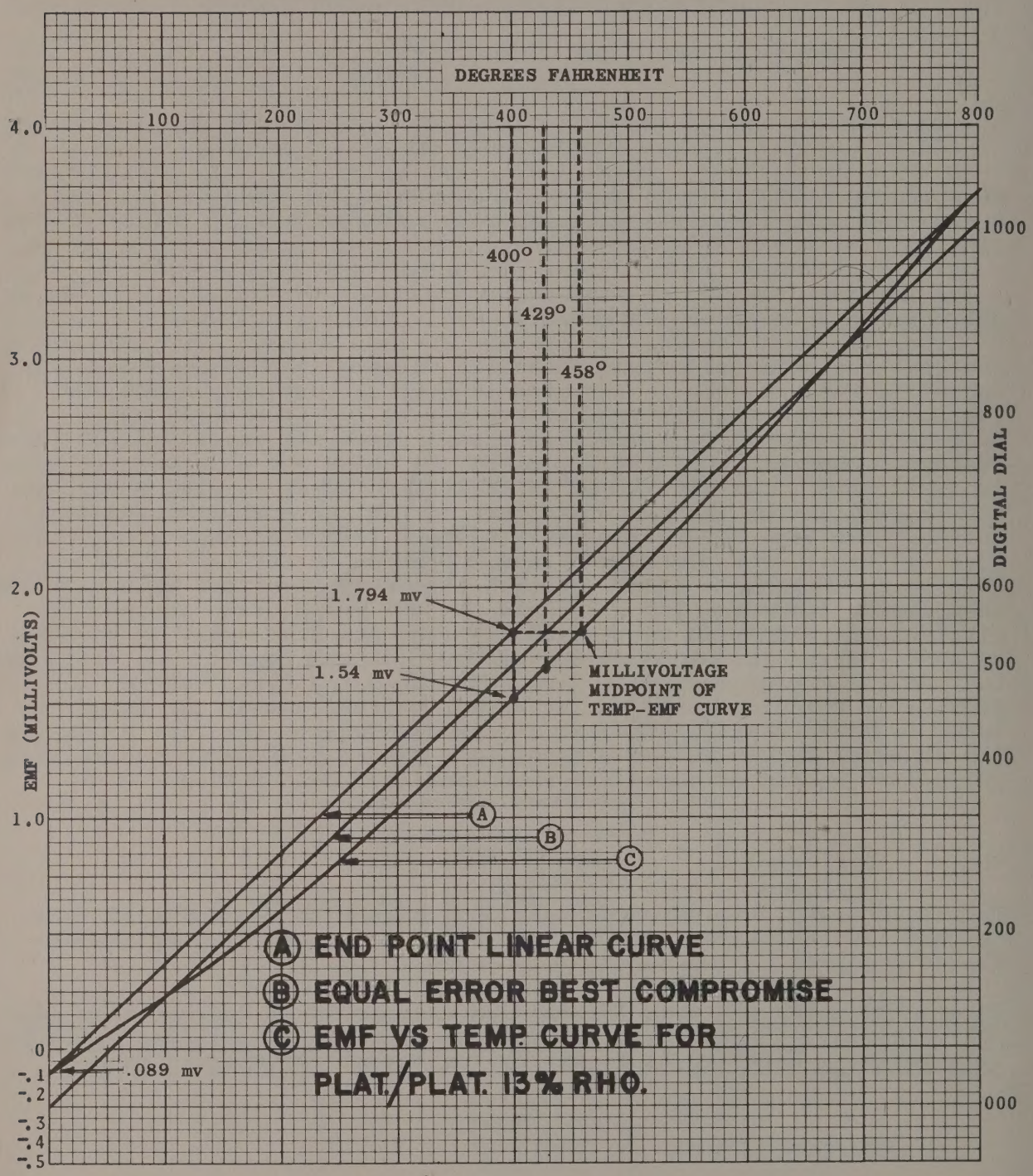

DEGREES FAHRENHEIT
100
200
300
400
500
600
700
800
4.0
3.0
2.0
1.0
0
-.1
-.2
-.3
-.4
-.5
EMF (MILLIVOLTS)
1000
800
600
500
400
200
000
DIGITAL DIAL
400°
429°
458°
1.794 mv
1.54 mv
.089 mv
MILLIVOLTAGE MIDPOINT OF TEMP-EMF CURVE
A
B
C
A END POINT LINEAR CURVE
B EQUAL ERROR BEST COMPROMISE
C EMF VS TEMP. CURVE FOR PLAT./PLAT. 13% RHO.

Fig. 5

Calibration of Dial for Millivolts

Millivolt calibrations down to 5 millivolts are standard and present no linearity problems. These are furnished in all suppressions up to 100 millivolts.

Galvanometer Scale Sensitivity or Equivalent Range

It is often helpful to be able to estimate the indicated temperature, on the scale of the 400 Series Meter, when the pointer deflection is other than at zero (or null). This information may be particularly desired during the start-up period of a heating process, or when calculating controller gain or proportional band.

When a temperature difference exists between the dial setting of the Reference Voltage Source and the thermocouple, a current will flow through the galvanometer causing pointer deflection. The amount of current, and hence the degree of deflection from zero, is a function of this temperature difference, thermocouple calibration and internal resistance of the system.

The amount of current flow may be expressed by the formula

$$E_{\Delta} = I_m R_t$$

where:

E_{Δ} = Voltage difference between Series 350 dial setting (or equivalent millivoltage if calibrated in temperature), and thermocouple EMF when galvanometer indicator is at either end of scale.

I_m = Galvanometer current

(a) Use 25 microamperes for half-scale deflection of #15 springs (used for range spans of less than 25 millivolts).

(b) Use 35 microamperes for half-scale deflection of #20 springs (used for range spans of 25 millivolts or more).

R_t = Total resistance of galvanometer plus the Series 350.

(a) Use 115 ohms as the internal resistance of the 400 Series instrument.

(b) The internal resistance of the Series 350 Reference Voltage Source varies according to range, suppression and type of thermocouple. Usually it will vary between 25 and 80 ohms, but may be as low as zero

for uncompensated millivolt ranges starting from zero millivolts. The most convenient method of determining internal resistance is with a Wheatstone bridge or ohmmeter connected between terminals G+ and TC+, with the instrument isolated from all other circuits.

Example:

The ohmmeter readings from TC+ to G+ on a Model 351T, range 700-1200°C, platinum - platinum, 13% rhodium thermocouple, indicates an internal resistance ranging between 40 and 60 ohms throughout the dial setting of from 0 to 1000. Using an average internal resistance of 50 ohms, the calculation of the scale range for the 400 Series instrument is as follows:

$$E_{\Delta} = I_m R_t$$

$$E_{\Delta} = 25 \text{ microamperes} \times (50 + 115 \text{ ohms})$$

$$= 4.125 \text{ millivolts difference}$$

With the set point at the midpoint of the range (950°C, or at 500 digits on the dial), the reference voltage input would be 9.816 millivolts. This amount, minus the E value of 4.125 millivolts, is the equivalent of 611°C thermocouple temperature with the indicator needle at the extreme left side or low temperature end of the scale. Adding 4.125 millivolts to the set point millivoltage of 9.816 results in an equivalent temperature of 1254°C as the unrestricted maximum deflection to the right of the scale.

The 400 Series scale may thus be said to be indicating from 611°C at the low end, through 950°C at mid-scale to 1254°C at the high end. Positions of the indicator between these points may be roughly estimated. (The difference between upscale and downscale temperature, from the mean temperature, is due to non-linearity of the EMF curve).

Galvanometer Characteristics

When the Model 350 reference voltage source is used with a control system, the gain and response characteristics of the galvo will effect the type of control obtained.

Control System Gain:

The sensitivity of the galvo is an important component in the control loop and its gain contributes to the total loop gain. Gain is inverse to proportional band. Thus gain can be reduced, if necessary, by reducing the galvanometer sensitivity. This is easily done in the field by increasing the galvanometer resistance by a series dropping resistance. This is conveniently installed at the terminals located in rear of lower chassis housing.

Control Element Damping:

The response or time constant of the measuring element is a damping function. Low external resistance to the galvo will result in a slow over-damped needle response. This is not generally advantageous to control, but may be the result of a particular reference voltage source calibration. The addition of series resistance tends to speed up the galvo response and, if carried to extremely high resistance, will result in an under-damped action.

Result of Series Resistance:

If the process time constant is fairly large; say, greater than one minute, the system will undoubtedly be stable. Faster processes tend to reduce the margin between the control system time constant and process, thus requiring reduced gain to give stability. If the controller P.B. is not sufficiently wide nor other gain reductions used, the galvo sensitivity can be reduced by series resistance addition. The insertion of series resistance also decreases the damping which generally improves control action. A series resistance of 250 ohms should be a maximum value for usual installations. If stability cannot be reached with this value, look elsewhere in the system for components with unusually large time lags or hysteresis. Control of systems with a time constant less than about 10 seconds cannot be controlled with this equipment. The addition of series resistance has no effect on the static calibration of the temperature measuring function when at the null balance point.

Tuning Instructions

Upon initial installation and after connection to the 400 Series instrument, power the Series 350 and also power the 400 Series control chassis to determine proper control action. When used with a Model 401P or 402P, relay action can be observed by the signal lights. If the Model 407P is used as the control instrument, attach a Model 610A Pilot Amplifier (or other suitable load of approximately 5000 ohms) and a voltmeter (0-100 volts d-c).

The object of tuning is to:

1. Obtain fail safe conditions.
2. Obtain null or near null conditions at control point. (This will result in zero T/C current at, or near control point, to eliminate line resistance effect).

To obtain proper tuning, adjust the mechanical zero of the galvanometer one or two millimeters to right (or up scale) of null or zero point. The mechanical zero adjustment screw is found on top of the 400 meter housing.

After mechanical zero adjustment, tune the 400 Series control chassis reset screw to obtain a near minimum (safe) power level into process at mechanical zero.

Recheck this condition after each proportional band and reset adjustment.

This adjustment insures minimum power level in case of thermocouple or lead wire break.

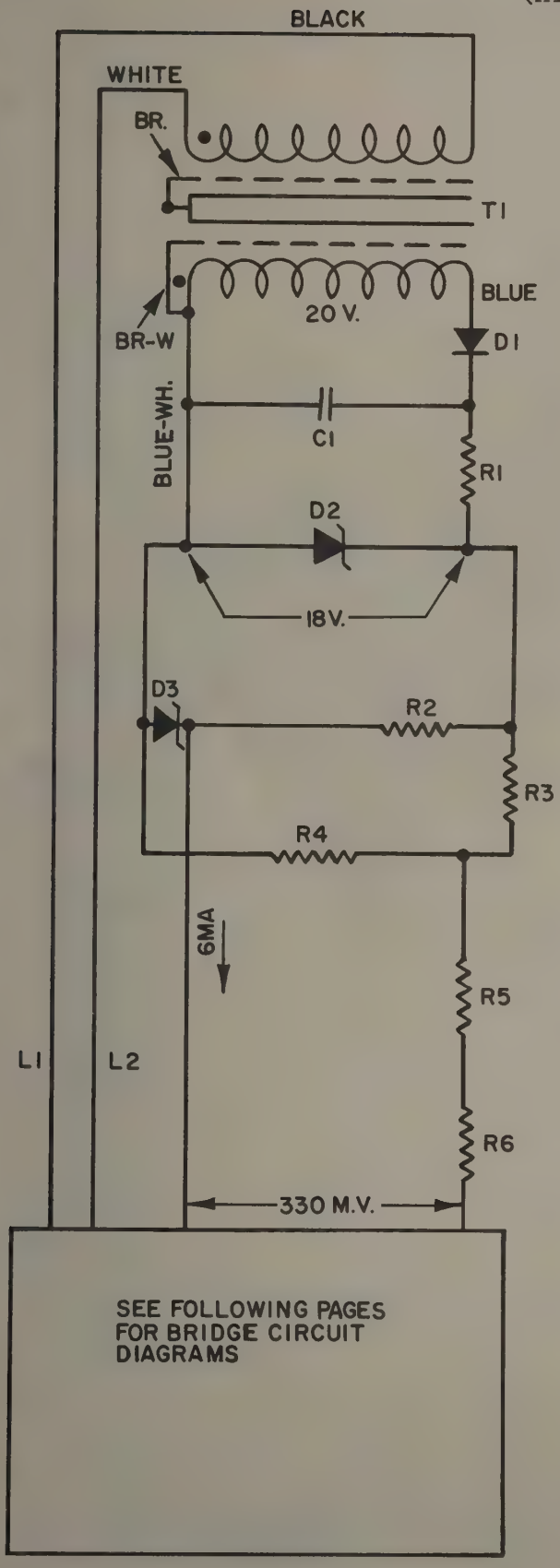
Series 350 Internal Circuit (Refer to circuit diagrams)

The reference voltage source contains a line voltage operated isolation transformer with a rectifier diode, followed by Zener diodes for voltage limiting. The source is stable to 3 microvolts with a 10% line voltage change. A ten turn linear precision potentiometer is utilized as a voltage divider, with an appropriate resistor network to suit specific ranges. A copper cold junction spool compensates for thermocouple cold junction variation and is located at the T/C terminal posts in order to immediately sense junction temperature conditions. The internal circuitry of the Series 350 and galvanometer is copper with all connections using low EMF solder.

The Series 350 is supplied in single, dual, or triple ranges which may be consecutive, overlapping or isolated. The power supply section of the circuitry is common to all models. The bridge circuit and switching arrangement is different for each model and calibration as shown on the schematics on the following pages.

Series 350 Power Supply Schematic
(All Models)

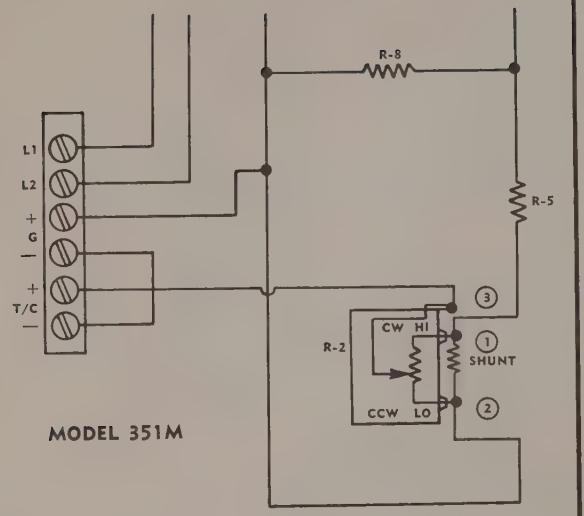
Effective August 1, 1962



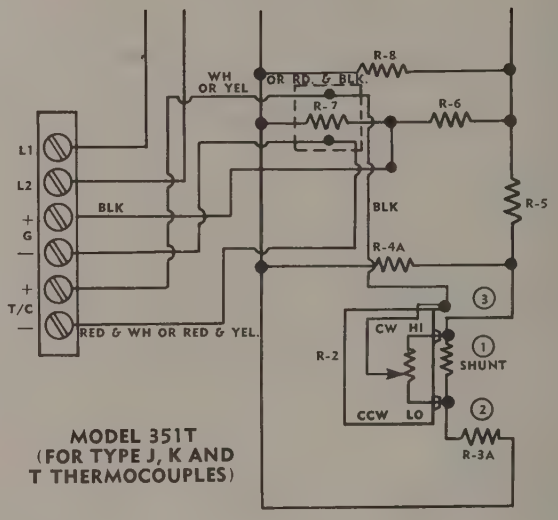
ITEM	PART NO.	DESCRIPTION
T1	30-126	TRANSFORMER
D1	EYZP 384	DIODE 500 MA @ 75 PIV
D2	31-046	IN3026 ZENER DIODE 18V ± 20%
D3	31-027	IN2163 ZENER DIODE 9-9.8V
C1	39-163	100 MFD. 50V CAPACITOR
R1	40-233	270 ± 1W. CARBON RESISTOR
R2	40-160	529.81Ω ± 1% W.W. RESISTOR
R3	40-162	10KΩ ± 1% W.W. RESISTOR
R4	40-161	232.15Ω ± 1% W.W. RESISTOR
R5	40-163	1KΩ ± 1% W.W. RESISTOR
R6	A-4409	CALIBRATING SPOOL

Fig. 6

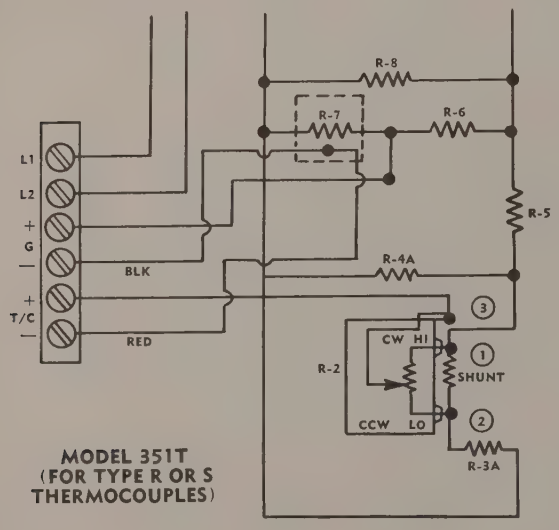
SERIES 350 BRIDGE CIRCUIT SCHEMATICS



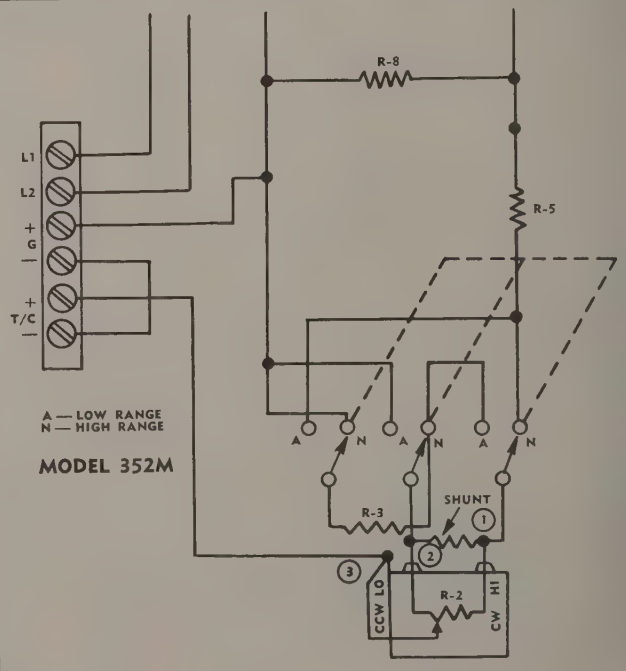
MODEL 351M



MODEL 351T
(FOR TYPE J, K AND
T THERMOCOUPLES)



MODEL 351T
(FOR TYPE R OR S
THERMOCOUPLES)



MODEL 352M

Fig. 7

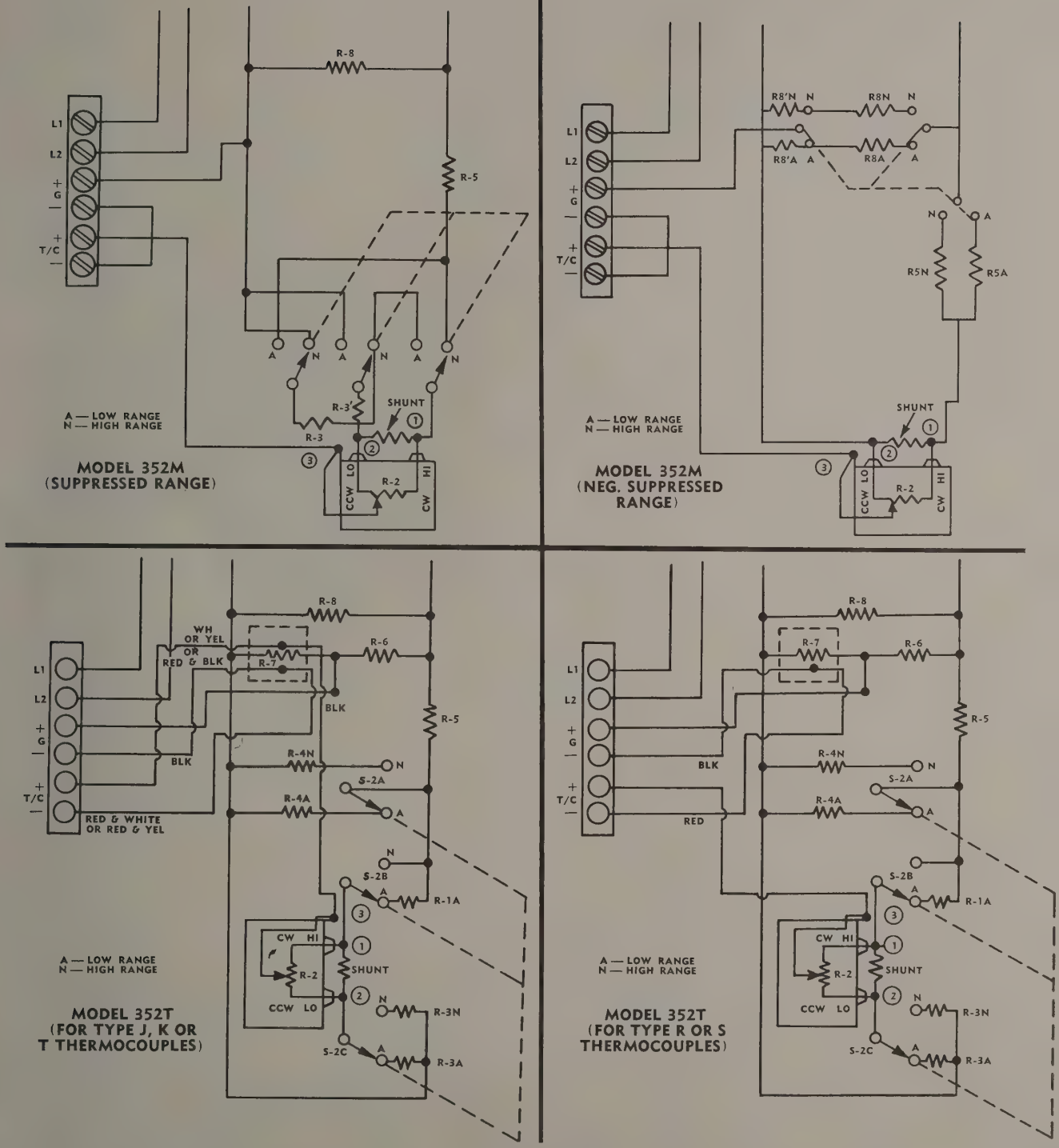

L1
L2
+ G —
+ T/C —
R-8
R-5
A N A N A N
R-3'
SHUNT
R-3
R-2
CCW LO
CW HI
A — LOW RANGE
N — HIGH RANGE
MODEL 352M
(SUPPRESSED RANGE)
R8'N N
R8N N
R8'A A
R8A A
R5N
R5A
MODEL 352M
(NEG. SUPPRESSED
RANGE)
WH OR YEL OR RED & BLK
R-7
R-6
BLK
R-4N
R-4A
S-2A
S-2B
R-1A
S-2C
R-3N
R-3A
RED & WHITE OR RED & YEL
MODEL 352T
(FOR TYPE J, K OR
T THERMOCOUPLES)
RED
MODEL 352T
(FOR TYPE R OR S
THERMOCOUPLES)

Fig. 8

Standard Ranges and Error Limits

Following is a list of standard ranges for the Series 350 Reference Voltage Source, showing also the limits of error to be expected for each range. The selection of range for a particular application must consider the measurement error acceptable. When close accuracy is required, it is recommended that a unit calibrated in millivolts with cold junction compensation be specified. This would then eliminate the greater error due to thermocouple non-linearity.

Calculated maximum limits of error, as shown, are those due to EMF temperature non-linearities* (for instruments calibrated in temperature) and maximum errors due to production tolerance of the instrument. The table below shows additional errors due to the standard limits of error of the thermocouple material. These errors are additive (algebraically) for determining total maximum error possible for a given dial setting.

THERMOCOUPLE LIMITS OF ERROR

Calibration	Temperature Range	Standard Limits of Error*
	- 300 to - 75°F	----
Copper-Constantan	- 150 to - 75°F	± 2 %
	- 75 to + 200°F	± 1-1/2%
	200 to 700°F	± 3/4%
Iron-Constantan	0 to 530°F	± 4°F
	530 to 1400°F	± 3/4%
Chromel-Alumel	0 to 530°F	± 4°F
	530 to 2300°F	± 3/4%
Platinum-Rhodium-Platinum	0 to 1000°F	± 5°F
	1000 to 2700°F	± 0.5%

From I.S.A. Recommended Practice R. P. 1.3

*See Fig. 5

SERIES 350 STANDARD RANGES

Millivolt (Uncompensated)

Code Number	Millivolt Ranges	Error:* EMF vs Temp.	Error ± Prod. Tol.	Remarks
441	0-1	---	.01 mv	
1442	-5.0-0-5.0	---	.03 mv	
1430	-5.0-0-5.0	---	.03 mv	Dual Range
	-10.0-0-10.0	---	.05 mv	
1438	0-10.0	---	.05 mv	
1472	0-5	---	.03 mv	Dual Range
	5-10	---	.05 mv	
1441	5.22-13.13	---	.06 mv	
1439	0-15	---	.07 mv	
1435	0-10	---	.05 mv	Dual Range
	0-20	---	.09 mv	
1482	0-5	---	.03 mv	Triple Range
	4-14	---	.06 mv	
	13-23	---	.10 mv	
1434	5-15	---	.07 mv	Dual Range
	15-25	---	.11 mv	
1429	0-15	---	.07 mv	Dual Range
	15-30	---	.13 mv	
1432	0-20	---	.09 mv	Dual Range
	20-40	---	.17 mv	
1431	20-30	---	.13 mv	Dual Range
	30-40	---	.17 mv	
1437	-5-0-5	---	.03 mv	Dual Range
	-40-0-40	---	.17 mv	
1483	0-22	---	.10 mv	Triple Range
	22-32	---	.14 mv	
	32-42	---	.17 mv	
1440	8-44	---	.19 mv	
1436	0-25	---	.11 mv	Dual Range
	25-50	---	.21 mv	
1433	39-46	---	.19 mv	Dual Range
	46-53	---	.22 mv	
1456	0-50	---	.21 mv	Dual Range
	0-500	---	2.0 mv	

COPPER-CONSTANTAN (TYPE T)

	Fahrenheit Ranges		
606	-100-0-350°F	+13.°F	1.8°F
1425	- 90-0-500°F	+19.°F	2.4°F

	Millivolt Ranges (Temp. Compensated)		°F	MV	°C
1428	-2.7-0-8.3	----	1.7	.10	1.0
1426	-2.6-0-10.6	----	2.1	.11	1.2
1427	-2.6-0-12.6	----	2.3	.12	1.3

NOTE: *
+ sign designates actual temperature above indicated at midrange.
- sign designates actual temperature below indicated at midrange.

SERIES 350 STANDARD RANGES

IRON-CONSTANTAN (TYPE J)

Code Number	Fahrenheit Ranges	Error:* EMF vs Temp.	Error ± Prod. Tol.	Remarks
56	0-400°F	+2-1/2°F	1.9°F	
306	0-500°F	+3-1/2°F	2.3°F	
17	0-1000°F	+3-1/2°F	4.3°F	
193	500-1000°F	+ 1/2°F	4.3°F	
1161	0-500°F	+3-1/2°F	2.3°F	Dual Range
	500-1000°F	+ 1/2°F	4.3°F	
1448	-200-+300°F	+10°F	1.5°F	Triple Range
	300-800°F	+0 °F	3.5°F	
	800-1300°F	+4 °F	5.5°F	
	Centigrade Ranges			
99	0-250°C	+1-1/2°C	1.2°C	
21	0-300°C	+1 °C	1.4°C	
1384	-100-400°C	+5-1/2°C	1.8°C	
23	0-500°C	+1-1/2°C	2.2°C	

	Millivolt Ranges (Temp. Compensated)		°F	MV	°C	
1497	0-10 mv	----	1.7°F	.06 mv	.9°C	Dual Range
	5-15 mv	----	2.4°F	.08 mv	1.3°C	
1387	5-15 mv	----	2.4°F	.08 mv	1.3°C	Dual Range
	15-25 mv	----	3.7°F	.12 mv	2.0°C	
1385	0-30 mv	----	4.3°F	.14 mv	2.4°C	
1386	0-50 mv	----	6.7°F	.22 mv	3.7°C	

SERIES 350 STANDARD RANGES

CHROMEL-ALUMEL (TYPE K)

Code Number	Fahrenheit Ranges	Error:* EMF vs Temp.	Error ± Prod. Tol.	Remarks
393	0-500°F	0 °F	2.4°F	
1504	100-600°F	0 °F	2.8°F	
586	500-1500°F	0 °F	6.4°F	
30	0-2000°F	-3 °F	8.4°F	
1349	0-500°F	0 °F	2.4°F	Dual Range
	500-1500°F	0 °F	6.4°F	
179	1000-2000°F	-7-1/2°F	8.4°F	
1351	0-500°F	0 °F	2.4°F	Dual Range
	1000-2000°F	-7-1/2°F	8.4°F	
1350	0-1000°F	+5 °F	4.4°F	Dual Range
	1000-2000°F	-7-1/2°F	8.4°F	
1353	1000-1500°F	-1-1/2°F	6.4°F	
	1500-2000°F	-2-1/2°F	8.4°F	
1354	200-1200°F	+5 °F	5.2°F	Dual Range
	1200-2200°F	-9 °F	9.2°F	
1352	100-1500°F	+4 °F	6.4°F	
1505	500-2100°F	-12 °F	8.8°F	
	Centigrade Ranges			
110	0-600°C	+2-1/2°C	2.6°C	
1336	200-350°C	0 °C	1.6°C	
988	150-450°C	+1-1/2°C	2.0°C	
1003	200-700°C	+1-1/2°C	3.0°C	
1356	600-700°C	0 °C	3.0°C	
692	400-800°C	-1-1/2°C	3.4°C	
1365	400-900°C	-2 °C	3.8°C	
33	0-1000°C	0 °C	4.2°C	
754	0-500°C	+2 °C	2.2°C	Dual Range
	500-1000°C	-2-1/2°C	4.2°C	
1357	0-600°C	+2-1/2°C	2.6°C	Dual Range
	600-1000°C	-2-1/2°C	4.2°C	
457	500-1000°C	-2-1/2°C	4.2°C	
1358	750-1050°C	-1-1/2°C	4.4°C	
1360	800-1100°C	-2-1/2°C	4.6°C	
1361	200-700°C	+1-1/2°C	3.0°C	Dual Range
	600-1100°C	-3 °C	4.6°C	
34	0-1200°C	-6 °C	5.0°C	
1363	700-1200°C	-4 °C	5.0°C	
1355	0-600°C	+2-1/2°C	2.6°C	Dual Range
	600-1200°C	-6 °C	5.0°C	
1359	300-1300°C	-12 °C	5.4°C	
1364	800-1300°C	-5 °C	5.4°C	
1362	500-1000°C	-2-1/2°C	4.2°C	Dual Range
	1000-1500°C	-4 °C	6.2°C	

SERIES 350 STANDARD RANGES

CHROMEL-ALUMEL (TYPE K)

Code Number	MV Ranges (Temp. Comp.)	Error:* EMF vs Temp.	Error ± Prod. Tol. °F	Error ± Prod. Tol. MV	Error ± Prod. Tol. °C	Remarks
1381	5-15 mv	---	3.4 °F	.08 mv	1.9 °C	
1367	15-25 mv	---	5.1 °F	.12 mv	2.8 °C	Dual Range
	21-31 mv	---	6.1 °F	.14 mv	3.4 °C	
1374	15-25 mv	---	5.1 °F	.12 mv	2.8 °C	Dual Range
	26-36 mv	---	7.0 °F	.16 mv	3.9 °C	
1375	18-28 mv	---	5.6 °F	.13 mv	3.1 °C	Dual Range
	27-37 mv	---	7.1 °F	.16 mv	3.9 °C	
1369	20-30 mv	---	6.0 °F	.14 mv	3.3 °C	Dual Range
	27-37 mv	---	7.1 °F	.16 mv	3.9 °C	
1366	10-30 mv	---	6.0 °F	.14 mv	3.3 °C	Dual Range
	28-38 mv	---	7.4 °F	.17 mv	4.1 °C	
1382	20.65-41.31 mv	---	8.0 °F	.18 mv	4.4 °C	
1376	20-42 mv	---	8.1 °F	.18 mv	4.5 °C	
1443	10-20 mv	---	4.3 °F	.10 mv	2.4 °C	Triple Range
	20-30 mv	---	6.0 °F	.14 mv	3.3 °C	
	30-42 mv	---	8.1 °F	.18 mv	4.5 °C	
1447	12-22 mv	---	4.6 °F	.10 mv	2.6 °C	Triple Range
	22-32 mv	---	6.3 °F	.14 mv	3.5 °C	
	32-42 mv	---	8.1 °F	.18 mv	4.5 °C	
1483	2-22 mv	---	4.6 °F	.10 mv	2.6 °C	Triple Range
	22-32 mv	---	6.3 °F	.14 mv	3.5 °C	
	32-42 mv	---	8.1 °F	.18 mv	4.5 °C	
1512	5-25 mv	---	5.1 °F	.11 mv	2.8 °C	Dual Range
	23-43 mv	---	8.3 °F	.19 mv	4.6 °C	
1372	20-45 mv	---	8.7 °F	.19 mv	4.8 °C	
1373	0-50 mv	---	9.0 °F	.21 mv	5.0 °C	
1380	10-30 mv	---	6.0 °F	.14 mv	3.3 °C	Dual Range
	30-50 mv	---	9.0 °F	.21 mv	5.0 °C	
1444	5-20 mv	---	4.3 °F	.10 mv	2.4 °C	Triple Range
	20-35 mv	---	6.8 °F	.15 mv	3.8 °C	
	35-50 mv	---	9.0 °F	.22 mv	5.0 °C	
1464	10-20 mv	---	4.3 °F	.10 mv	2.4 °C	Triple Range
	30-40 mv	---	7.7 °F	.17 mv	4.3 °C	
	40-50 mv	---	9.0 °F	.21 mv	5.0 °C	
1470	20-30 mv	---	6.0 °F	.14 mv	3.3 °C	Triple Range
	30-40 mv	---	9.0 °F	.17 mv	4.3 °C	
	40-50 mv	---	9.0 °F	.22 mv	5.0 °C	
1377	32-42 mv	---	8.1 °F	.18 mv	4.5 °C	Dual Range
	41-51 mv	---	9.2 °F	.22 mv	5.1 °C	
1445	21-31 mv	---	6.1 °F	.14 mv	3.4 °C	Triple Range
	31-41 mv	---	7.9 °F	.18 mv	4.4 °C	
	41-51 mv	---	9.2 °F	.22 mv	5.1 °C	
1378	32-52 mv	---	10.0 °F	.22 mv	5.6 °C	
1383	32-42 mv	---	8.1 °F	.18 mv	4.5 °C	Dual Range
	42-52 mv	---	10.0 °F	.22 mv	5.6 °C	
1446	22-32 mv	---	6.3 °F	.14 mv	3.5 °C	Triple Range
	32-42 mv	---	8.1 °F	.18 mv	4.5 °C	
	42-52 mv	---	10.0 °F	.22 mv	5.6 °C	
1379	33-43 mv	---	8.3 °F	.19 mv	4.6 °C	Dual Range
	43-53 mv	---	10.2 °F	.23 mv	5.7 °C	
1371	35-45 mv	---	8.7 °F	.19 mv	4.7 °C	Dual Range
	43-53 mv	---	10.2 °F	.23 mv	5.7 °C	
1370	36-46 mv	---	8.9 °F	.20 mv	5.0 °C	Dual Range
	43-53 mv	---	10.2 °F	.23 mv	5.7 °C	

SERIES 350 STANDARD RANGES

10% PLATINUM-RHODIUM (TYPE S)

Code Number	Fahrenheit Ranges	Error:* EMF vs. Temp.	Error ± Prod. Tol.	Remarks
1391	0-1000°F	+30 °F	5.4°F	
1388	2000-3000°F	- 1-1/2°F	13.4°F	
1389	2250-2750°F	- 1 °F	12.4°F	
1390	1000-2000°F	+11 °F	9.4°F	Dual Range
	2000-3000°F	- 1-1/2°F	13.4°F	
	Centigrade Ranges			
1394	0-600°C	+16 °C	3.2°C	Dual Range
	600-1200°C	+ 7 °C	5.6°C	
1397	500-1000°C	+ 5 °C	4.8°C	
1395	500-1500°C	+13-1/2°C	6.8°C	
651	700-1400°C	+ 6-1/2°C	6.4°C	
1392	1000-1500°C	+ -1/2°C	6.8°C	
106	0-1000°C	+28-1/2°C	4.8°C	
1507	0-1000°C	+28-1/2°C	4.8°C	Dual Range
	900-1400°C	+ 2 °C	6.4°C	
1396	500-1000°C	+ 5 °C	4.8°C	Dual Range
	1000-1500°C	+ -1/2°C	6.8°C	
1393	800-1300°C	+ 4 °C	6.0°C	Triple Range
	700-1200°C	4-1/2°C	5.6°C	
	1200-1700°C	-1 °C	7.6°C	

	Millivolt Ranges (Temp. Compensated)		°F	MV	°C	
1402	5-10 mv	----	9.2°F	.05 mv	5.1°C	
1400	3-13 mv	----	11.0°F	.06 mv	6.1°C	
1490	0-10 mv	----	9.2°F	.05 mv	5.1°C	Dual Range
	3-13 mv	----	11.0°F	.06 mv	6.1°C	
1398	0-10 mv	----	9.2°F	.05 mv	5.1°C	Dual Range
	5-15 mv	----	12.2°F	.07 mv	6.8°C	
1399	0-15 mv	----	12.2°F	.07 mv	6.8°C	
1469	5-10 mv	----	9.2°F	.05 mv	5.1°C	Dual Range
	10-15 mv	----	12.2°F	.07 mv	6.8°C	
1401	0-8 mv	----	8.0°F	.04 mv	4.4°C	Dual Range
	8-16 mv	----	12.8°F	.07 mv	7.1°C	
1489	7-17 mv	----	13.4°F	.08 mv	7.4°C	
1506	0-18 mv	----	14.0°F	.08 mv	7.8°C	
1403	0-10 mv	----	9.2°F	.05 mv	5.1°C	Dual Range
	8-18 mv	----	14.0°F	.08 mv	7.8°C	

SERIES 350 STANDARD RANGES

13% PLATINUM-RHODIUM (TYPE R)

Code Number	Fahrenheit Ranges	Error:* EMF vs Temp.	Error ± Prod. Tol.	Remarks
1406	1500-2000°F	+ 3-1/2°F	9.4°F	
557	1500-2500°F	+ 7-1/2°F	11.4°F	
1405	1800-2300°F	+ 2 °F	10.4°F	Dual Range
	2300-2800°F	0 °F	12.6°F	
38	0-3000°F	+108 °F	13.4°F	
1404	1000-2000°F	+ 13-1/2°F	9.4°F	Dual Range
	2000-3000°F	0 °F	13.4°F	
1310	2000-3000°F	0 °F	13.4°F	
	Centigrade Ranges			
1409	0-500°C	+ 17 °C	2.8°C	Dual Range
	500-1000°C	+ 6 °C	4.8°C	
1411	500-1000°C	+ 6 °C	4.8°C	
1414	700-1200°C	+ 5-1/2°C	5.6°C	
1463	200-700°C	+ 8 °C	3.6°C	Dual Range
	700-1200°C	+ 6-1/2°C	5.6°C	
1410	900-1100°C	+ 1-1/2°C	5.2°C	Dual Range
	1100-1300°C	+ -1/4°C	6.0°C	
1408	800-1300°C	+ -1/2°C	6.0°C	
1511	300-1300°C	+ 22-1/2°C	6.0°C	
1492	850-1350°C	+ 8 °C	6.2°C	
1412	90-1400°C	+ 42 °C	6.4°C	
1416	700-1200°C	+ 5-1/2°C	5.6°C	Dual Range
	900-1400°C	+ 2-1/2°C	6.4°C	
1167	900-1300°C	+ 2-1/2°C	6.0°C	
736	400-1400°C	+ 20 °C	6.4°C	
812	800-1400°C	+ 1 °C	6.4°C	
980	900-1400°C	+ 1 °C	6.4°C	
521	500-1500°C	+ 17 °C	6.8°C	
1407	500-1000°C	+ 6 °C	4.8°C	Dual Range
	1000-1500°C	+ 1 °C	6.8°C	
1415	1000-1500°C	+ 1 °C	6.8°C	
1449	0-500°C	+ 17 °C	2.8°C	Triple Range
	500-1000°C	+ 6 °C	4.8°C	
	1000-1500°C	+ 1 °C	6.8°C	
39	0-1600°C	+ 58 °C	7.2°C	
1413	700-1200°C	+ 5-1/2°C	5.6°C	Dual Range
	1100-1600°C	0 °C	7.2°C	
700	800-1600°C	+ 5 °C	7.2°C	

SERIES 350 STANDARD RANGES

13% PLATINUM-RHODIUM

Code Number	MV Ranges (Temp. Comp.)	Error:* EMF vs Temp.		Error ± Prod. Tol.		Remarks
			°F±	MV±	°C±	
1421	5-15 mv	---	11.3°F	.07 mv	6.2°C	
1417	0-10 mv	---	8.7°F	.05 mv	4.8°C	Dual Range
	5-15 mv	---	11.3°F	.07 mv	6.2°C	
1424	0-16 mv	---	11.9°F	.07 mv	6.6°C	
1422	8-18 mv	---	12.9°F	.08 mv	7.1°C	
1418	0-10 mv	---	8.7°F	.05 mv	4.8°C	Dual Range
	8-12 mv	---	9.8°F	.06 mv	5.4°C	
1420	8-20 mv	---	14.0°F	.09 mv	7.7°C	
1419	4-14 mv	---	10.8°F	.07 mv	6.0°C	Dual Range
	10-20 mv	---	14.0°F	.09 mv	7.7°C	
1423	8-16 mv	---	11.9°F	.07 mv	6.6°C	
1465	0-10 mv	---	8.7°F	.05 mv	4.8°C	Dual Range
	6-16 mv	---	11.9°F	.07 mv	6.6°C	
1466	4-14 mv	---	10.8°F	.07 mv	6.0°C	

MATERIAL WARRANTY: All equipment except tubes, photocells and thermocouples, which within one year from date of shipment is found to have been originally defective, will be repaired (replaced if necessary) free of charge, if returned immediately, prepaid to the factory at Rockford, Illinois. The seller shall not be liable to the purchaser, or to any other person, firm or corporation for any direct, indirect or consequential damages or injury of any kind or character; that by acceptance of such equipment the purchaser shall accept and assume all liability for any and all damages or injuries that may result from the use or misuse of such equipment by the purchaser, or by any other person, firm or corporation; and that there shall be no other warranty whatever, expressed or implied, with respect to such equipment.

Warranty and Inspection Card — PLEASE FILL OUT AND RETURN

This equipment is guaranteed in accordance with the statement of warranty appearing on our quotation and acknowledgement forms. Upon receipt of this card properly filled out Warranty becomes effective. All Barber-Colman instruments are manufactured to the highest standards of quality and are carefully inspected before packing. Instruments which have been damaged or fail to operate upon installation, should be reported to the Factory at once.

BARBER-COLMAN COMPANY
Industrial Instruments Division

MODEL NO.
SERIAL NO.
CALIBRATION INSP.
FINAL INSPECTION

Date Received

Company

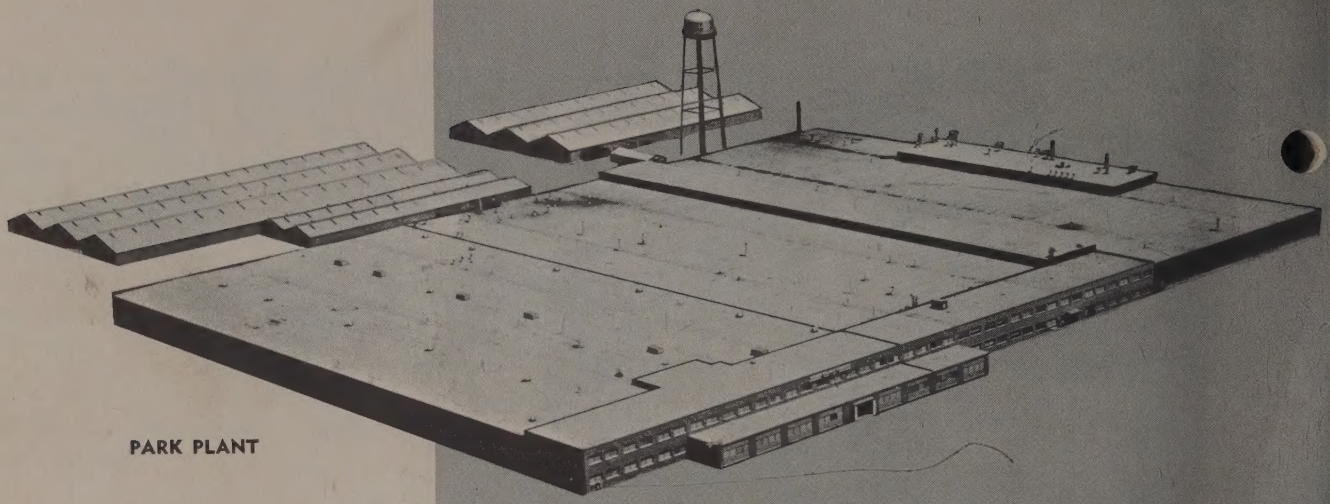
Street

City Zone State

By Title

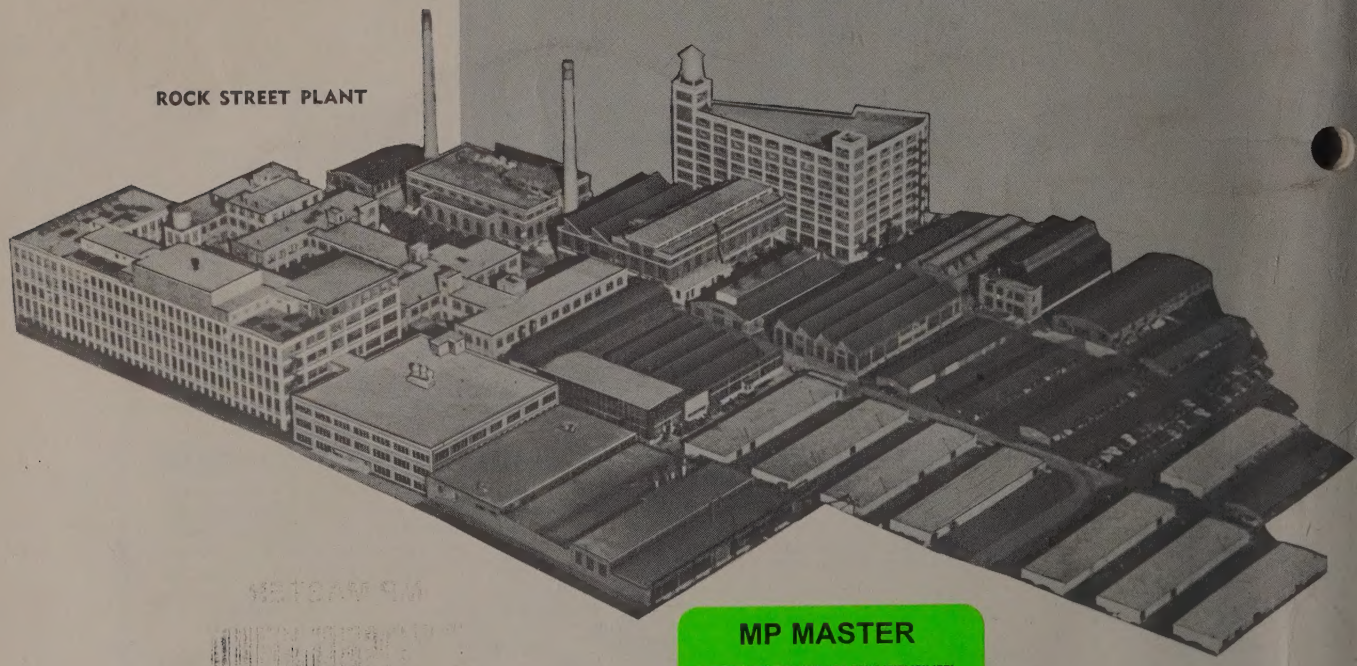
COMMENTS

COPY



PARK PLANT

ROCK STREET PLANT



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